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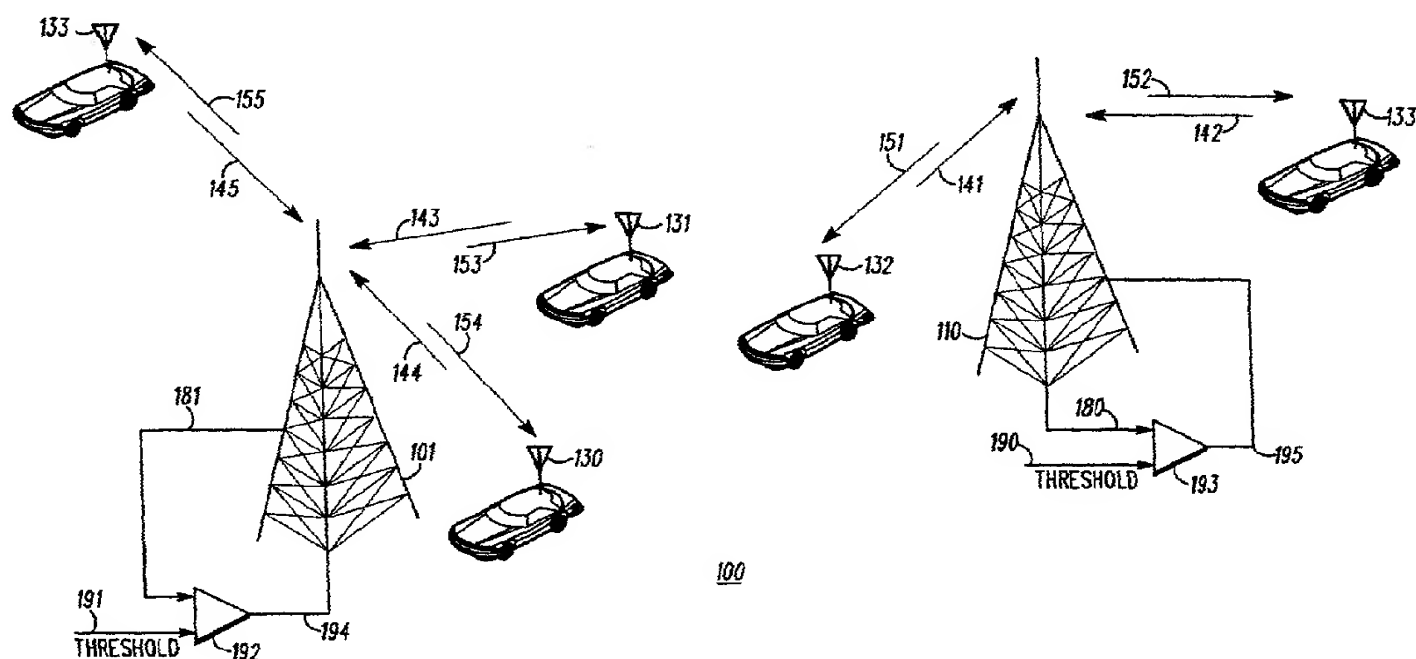
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(54) Title: TRANSMIT POWER CONTROL METHOD AND APPARATUS



(57) Abstract: A communication system (100) employing a power control scheme for downlink signals (151-155) transmitted to mobile stations (130-134).

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## Transmit Power Control Method and Apparatus

### Related Field of the Invention

Present invention relates to the field of communication systems, and more particularly, transmit power control techniques in a communication system.

### Background of the Invention

A frequency planning among closely located base stations in a communication system may be used such that the co-channel interference is minimized. For example, referring to FIG. 1, a base station 110 according to a frequency planning tries not to transmit at the same time on the same frequency as a base station 101 is transmitting. Such frequency planning minimizes co-channel interference. As such, for example, mobile stations 131 and 132 each communicating with different base stations experience minimal co-channel interference, however, co-channel interference is not entirely eliminated when base stations are not time synchronized. Two closely located base stations may for short period of time transmit on the same frequency.

To further minimize co-channel interference, in addition to a frequency planning, each base station utilizes a power control scheme to minimize transmission of signals thus limiting the power level. The level of interference on an RF channel normally is associated with the sum of the contributions from multiple RF transmitting sources. As such,

controlling RF power level minimizes the amount of the signal power level on a radio link to a level needed for an adequate communication quality. Power control in effect reduces the average amount of RF spectral energy surrounding the mobile and base stations, thus reducing the level of interference. The power control scheme may be implemented on downlink signals, transmitted from the base stations to the mobile stations, and uplink signals, transmitted from the mobile stations to the base stations. Power control of radio frequency signals transmitted from different sources in a communication system in different forms are known. The concept of power control is normally based on a feedback system. In particular, the specification for Global System Mobiles (GSM) communication system describes a method for controlling power level of downlink signals. The Global System for Mobile Communications (GSM) utilizes power control of mobile and base stations. Referring to FIG. 1, a communication system 100 employing a form of power control technique is shown. Such power control scheme may be according to the GSM standards. The communication system 100 may include one or more base stations such as base stations 101 and 110, each working independently providing communication services to a number of mobile stations, such as mobile stations 130-34. At different times, the number of mobile stations located in a geographic area receiving communication services may vary, although in this example only five mobile stations are shown. The

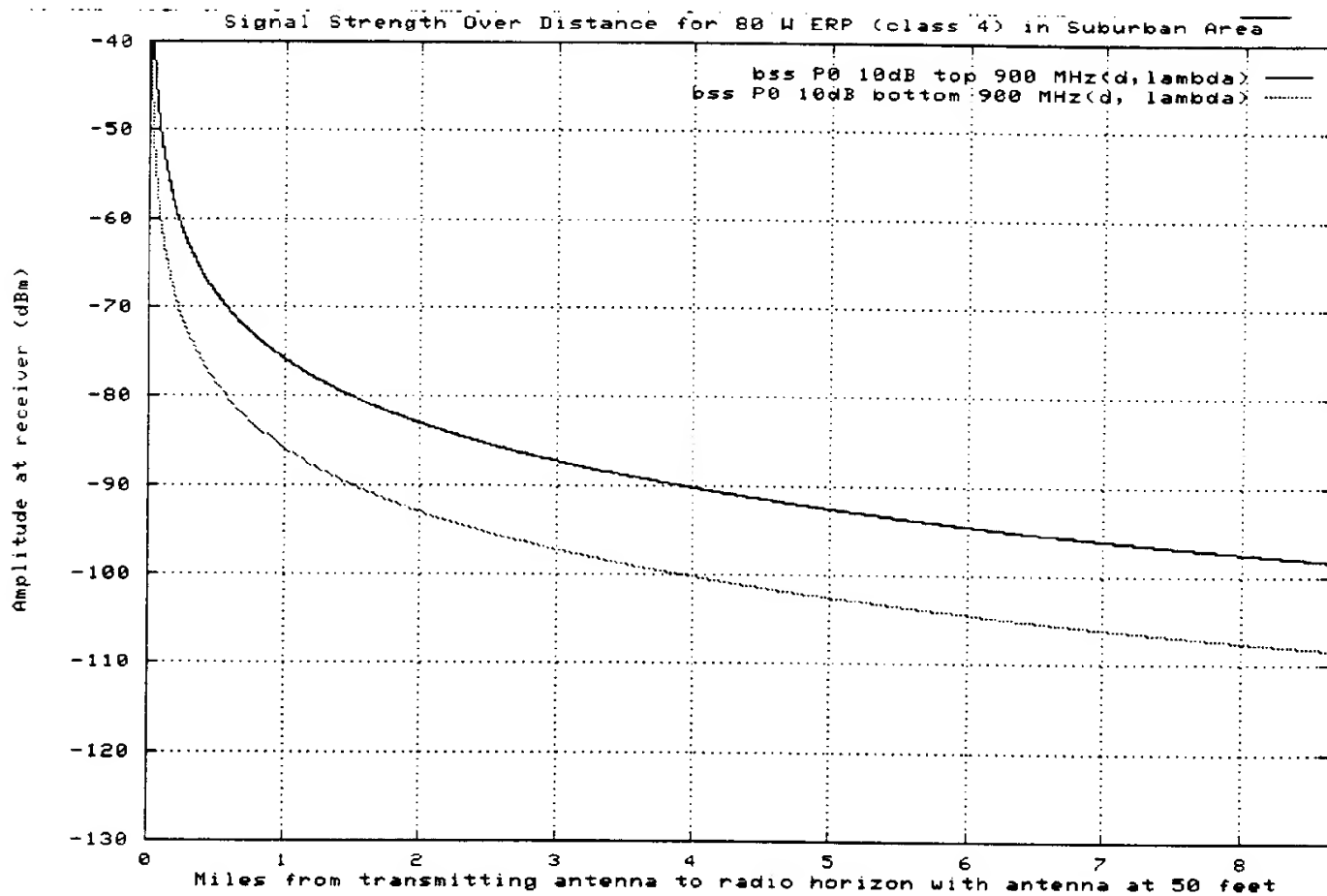
communication services may be provided according to a commonly known method of communication such as Time Division Multiple Access (TDMA) as described in the specification for the GSM system. Each mobile station communicates with a base station through down and uplink signals. The uplink signals 141-45 have respectively associated downlink signals 151-55.

For downlink RF power control, a base station receives from each mobile station, in communication with the base station, information or a report about quality of the signals received at each mobile station. Such information may include a quality of signal indicator and downlink signal power level received at each mobile station. For example, the information received at 180 and 181 are compared to thresholds 190 and 191 by comparators 193 and 192 respectively at base stations 110 and 101. Based on the comparison, downlink signal power level associated with the mobile station that reported the information is increased or decreased accordingly. Each downlink signal normally is controlled independently. The GSM specifications also define a power control for uplink RF signals which is dependent on the power output class of the mobile stations.

In GPRS mode, a GSM system may include at least one broadcast control channel (BCCH) and a number of downlink physical data channels (PDCH) providing communication services to the mobile stations. The

BCCH is broadcast at fixed power level for all mobile stations in the coverage area. As such, the BCCH channel normally is transmitted at the maximum power level allowable by the base station. The downlink power on the PDCH is limited by the GSM specifications to 10 dB below a certain reference level, commonly referred to "P0" level. The information regarding P0 is sent to the mobile stations in an assignment message. The base station after sending the value of P0 to a mobile station, should ensure that the downlink PDCH intended for that mobile station is transmitted at a power level between a range of power levels defined by a maximum and minimum power levels. The maximum and minimum power levels are calculated respectively according to (BCCH carrier level - P0) and (BCCH carrier level - P0 - 10 dB). The P0 value is used until the temporary block flow (TBF) in which the assignment message refers terminates or another assignment message is sent to the mobile station which re-assigns the value of P0. Depending on the downlink signal propagation condition between the base station and the mobile station, a new TBF message may be sent to the mobile station to correct for differences in the signal propagation at different times. The P0 parameter allows the mobile stations with limited received signal dynamic range some advance knowledge of how to set their receiver automatic gain control preventing a receiver signal over load. The following graph represent the maximum and minimum power level of a downlink signal

received at a mobile station for a P0 value with respect to the free space distance between the mobile station and a base station.



The range of signals received at the mobile stations close to the base station, for example, 1 mile away in free space, is between -75 to -85 dBm. For a mobile station at 7 miles away, for example, the range is between -95 to -105 dBm. Therefore, for a mobile station at 7 miles away in free space, the P0 value must be different than for a mobile station at 1 mile away in free space. Environmental conditions at different areas drastically changes

the propagation path loss characteristics such that two mobile stations close to the base station may require two different P0 values. The value of P0 parameter is determined according to the signal quality received at the base station. The TBF assignment message is used to change P0 value  
5 when signal quality drops below a threshold.

The communication services provided by a communication system, such as communication system 100, may include communication of voice and data services. The Global Packet Radio Services (GPRS) is a feature of the GSM system for the purpose of communicating data, i.e. non-voice,  
10 between mobile stations and base stations. The standards for communicating data are according to a form of packet switched communication as explained in the GSM standards, a copy of the specification may be obtained by contacting *ETSI, F-06921 Sophia Antipolis Cedex -FRANCE*, or accessing the web site [www.etsi.org](http://www.etsi.org) on the internet. An  
15 important part of GPRS standard may include providing communication of data service to more than one mobile stations in GPRS mode. For example, base station 101 may be in GPRS mode communication with mobile stations 130 and 131. When communication with a mobile station is in GPRS mode, i.e. packet switched mode, the base station may transmit  
20 data to the mobile station on a few time slots until data transfer is completed.

To begin a data transfer via packet data switching in GPRS mode, the mobile station and base station go through a series of setup sequences exchanging necessary information for data transfer to begin. Once the data transfer is completed, the mobile station and base station go through a  
5   teardown sequence to terminate the data transfer. During the data transfer period, the base station may transmit data to the mobile station on a downlink signal on a series of time slots which were previously assigned by the base station and communicated to the mobile station. In another way, the base station may dynamically allocate a series of time slots on the  
10   downlink to transfer an entire block of data to the mobile station. There may be more than one block of data to be transmitted during the data transfer period. Each block of data is interleaved across four TDMA frames with a portion of the data sent on one time slot in each of the four frames. The time slots in dynamic allocation mode are selected from a  
15   series of time slots predefined according to the mobile station "multi-slot-class" information communicated between the base station and mobile station.

Each mobile station normally after a setup sequence monitors the time slots defined by the base station. The slots are selected from the  
20   mobile station multi-slot-class. Two or more mobile stations may have multi-slot-classes that are either the same or share at least one common



time slot. As a result, two or more mobile stations may be monitoring the same time slots for receiving downlink information. For example, there may be at least 29 different multi slot classes. A mobile station belonging for example to a multi slot class 24 may be required to monitor all time slots from the first time slot to the 8<sup>th</sup> time slot in a time frame consisting of essentially 8 time slots. A mobile station belonging, for example, to multi slot class 3, may be required to monitor all time slots from the first time slot to the second time slot. Mobile stations in communication with a base station normally operate according to a time synchronization as defined by the base station. Therefore, two or more mobile stations in communication with the same base station may be monitoring the same time slot for detecting and receiving downlink information. The data is tagged such that it identifies the intended mobile station.

In dynamic allocation mode, a block of data may be transferred to a mobile station over four time slots in four consecutive TDMA frames. The downlink signal at each time slot selected for transmission of a block of data is required to have the same power level. Thus, all four time slots selected for transmission of a block of data intended for a mobile station are transmitted at the same power level.

Data in each time slot may have at least two data fields. The first field may contain uplink status flag (USF) followed by a data field

containing data of the block of data. Each mobile station has a unique identification associated with the data bits in the USF field. To give an immediate uplink access to a mobile station, the base station places the USF identity of a mobile station in the USF field to give that mobile station  
5 an immediate access to an uplink time slots. If the value of the USF bits is the same as the value assigned to a mobile station, the mobile station after detecting the USF bits may transmit on uplink on the same time slot of the next frame that received the USF field. The mobile station decides whether to transmit according to the allowed time slots. The mobile station  
10 identified by the USF field may be different than the mobile station that the data field is intended. The mobile stations with common multi-slot-class monitoring all time slots in the class makes possible that the USF field be intended for one mobile station and data field for another in one time downlink time slot.

15 The environment through which the downlink signals propagates may be entirely different for each mobile station. Mobile stations, although close in proximity, may receive signals transmitted from a base station at entirely different power levels because, for example, an obstacle such as a building hides one mobile station line of sight. Such mobile stations while  
20 monitoring the time slots as defined by their multi-slot-class may require different downlink signal power levels. When the downlink signal is

transmitted to a mobile station, the power control feedback loop may set the power level necessary for adequate reception at the intended mobile station. As such, the P0 value set for a mobile station intended to receive the USF field data may be different than the P0 value of another mobile  
5 station that the data field in intended.

In GPRS mode, all mobile stations with multi-slot-classes that share at least one common time slot may require different power levels for adequate reception. Since such mobile stations are required to monitor all time slots defined in their multi-slot-class for detection of USF field data or  
10 data field data, some mobile stations may experience difficulty detecting the data transmitted during such time slots. Some mobile stations depending on their locations or carrier to inference level with different downlink power level requirements may experience difficulty detecting the USF data that are tagged along with the data intended for another  
15 mobile station.

Therefore, there is a need for a power control scheme applied over the downlink signals such that USF data intended for one mobile station and data field data intended for another mobile station are adequately received at both mobile stations.

### Brief Description of the Drawings

FIG. 1 depicts a communication system 100 employing a power control scheme for downlink signals transmitted to mobile stations.

### 5 Detailed Description of the Preferred Embodiment(s)

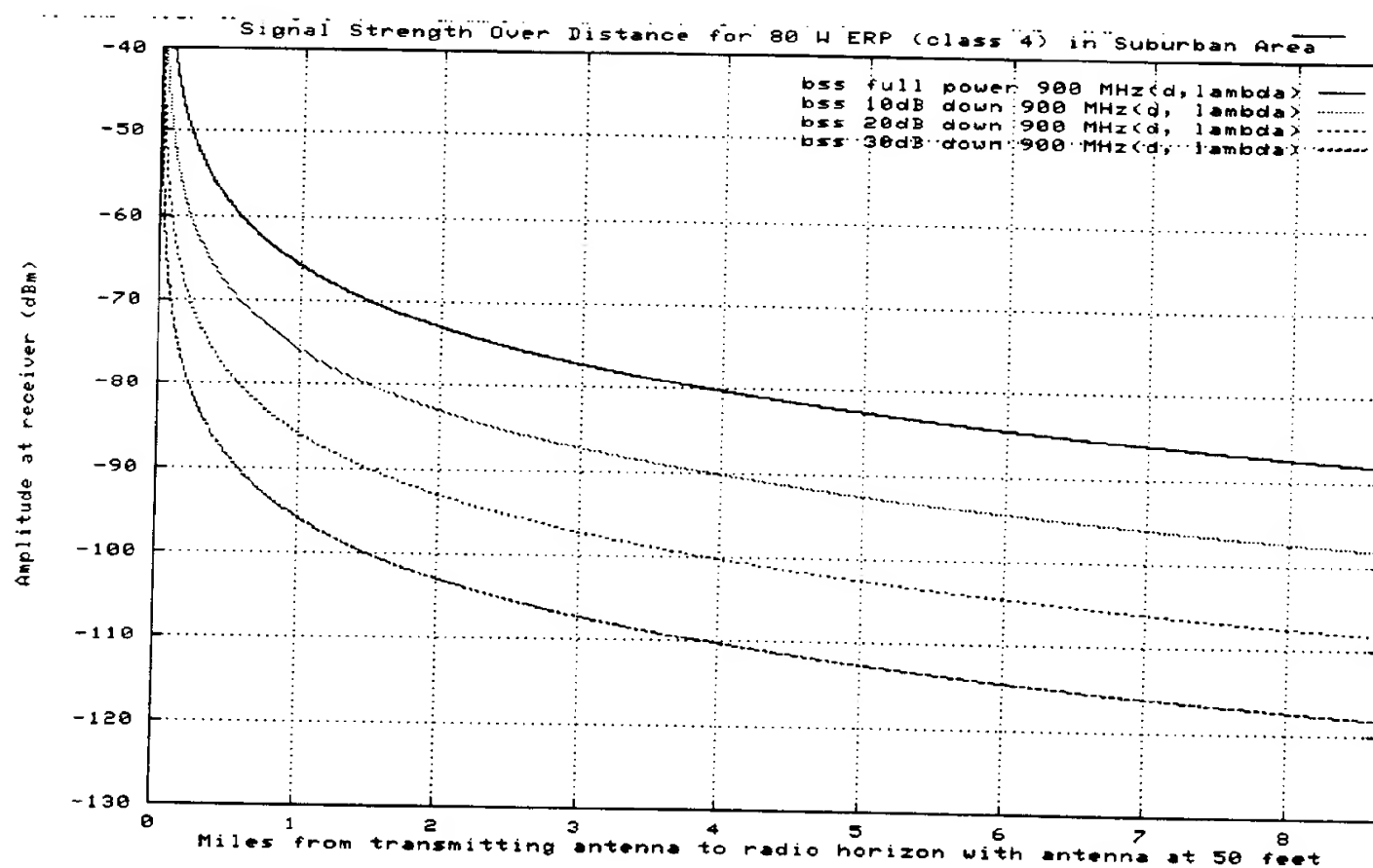
According to various aspects of the invention, in a communication system, a method may include grouping a plurality of mobile stations into a plurality of groups of mobile stations, and assigning a power control range to each group of the plurality of groups of mobile stations, thereby,  
10 creating a plurality of power control ranges corresponding to the plurality of groups of mobile stations. Each power control range has a minimum and maximum power level. As such, in GPRS mode, all mobile stations with multi-slot-classes that share at least one common time slot and are located in proximity of each other with similar downlink power control  
15 requirement may be assigned a power control range for adequate downlink signal reception. The mobile stations grouped in one group are required to monitor all time slots defined in their multi-slot-class for detection of data in the USF field or data field. The mobile stations grouped in one group each having a multi-slot class that shares at least  
20 one time slot may not experience difficulty detecting the data or the USF

data transmitted during such time slots. According to an aspect of the invention, at least a downlink signal transmitted from a base station to at least one of the plurality of mobile stations is controlled according to one of the plurality of power control ranges corresponding to one of the plurality of groups of mobile stations that includes the least one of the plurality of mobile stations.

The assignment of power control range may be based on determining location of at least one of the plurality of groups of mobile stations with respect to a base station providing communication services to the plurality of groups of mobile stations. The assignment may include alternatively or additionally based on the downlink signals reception quality at the plurality of the mobile stations. The grouping may be based on determining location of at least one of the plurality of mobile stations with respect to a base station providing communication services to the plurality of mobile stations.

The assignment of power control range may include assigning a power level reference value, such  $P_0$ , to each of the plurality of power control ranges. Furthermore, a base station may communicate the plurality of power control ranges to corresponding plurality of groups of mobile stations. Such communication may include communicating the assigned power reference value to the mobile stations in each group.

Various aspect of the invention may be more apparent in the following diagram.



For example, depending on the distance of the mobile station from the base station a different power control range may be assigned. For the mobile stations located at about 4-8 miles from the base station, the power control range may be limited to a power control range limited by the solid line shown in the above diagram and a lower value. For the mobile stations located between 1.5 to 4 miles from the base station, the power control range may be limited to a power control range limited by the dotted line below the solid line shown in the above diagram and a lower value. Similarly for other mobile stations. An application, filed with

USPTO with attorney docket number CS10114 Titled: Automatic Gain Control for a Receiver and Method Therefor, which is incorporated herein by reference, having at least a common named inventor with the present application, assigned to Motorola Inc., the assignee of the present  
5 application, discloses power control techniques for GPRS mode in a GSM communication system, in particular FIG. 11 of the incorporated reference shows four zones. Each zone has a maximum and minimum power levels assigned to a group of mobile stations. The zones as shown are selected according to distance of the mobile station from the base station.

10       The power control range may be viewed as zones of power control. Such zones may be dynamic, such that power control ranges change depending on the communication system condition. Some hysteresis between zones may be created to eliminate rapid reassignment of zones to mobile stations. A mobile station may be acceptable to be grouped into  
15 more than one zone. Power control ranges, i.e. zones may be adaptive in the event that much of the GPRS traffic is prevalent in an area. Some groups of mobile stations in GPRS mode may be within a certain distance from the base station antenna. In the case of areas of high population density using GPRS services, a zone may be dynamically created to absorb  
20 the high population density.

As the GPRS traffic is increased on the system, the problems with having to manage the transmit power level such that the downlink signal is suitable for more than one mobile station in which at least one mobile station is at a vastly differing distance from the base station antenna are  
5 greatly reduced.

A software algorithm or hardware in the base station implements the zoning of downlink power control range by dynamically creating and eliminating the power control zones, i.e. power control ranges. Another algorithm implements assignment to a mobile station a new zone when  
10 the mobile station crosses the boundary from one zone to another. The power control zones based upon carrier-to-interference and received power levels reported by the mobile station are of a logical nature, and may or may not be directly related to the distance between mobile and base station. Nevertheless, there may be exceptions to the path loss  
15 characteristics being a strict function of distance between mobile and base station antennas. There may exist conditions in which a mobile station is located near a base station antenna, but located inside a structure having a high amount of RF signal absorption. The timing advance of the communication between the base station and such closely located mobile  
20 station may indicate that the mobile station is nearby, but the carrier-to-interference and received power information reported by the mobile



would cause the base station to assign the mobile to a zone which may contain other mobiles which are much farther away, but logically within the same power control zone or range.

The algorithm for managing power control zones may be described  
5 in terms of a simplified representation of the GSM base station components and the mobile stations. The signaling plane between mobile station and base station may be with base station zoning logic. Upon receipt of an access burst from a mobile station, which arrives at the base station subsystem via one of the base station transceivers, the base station  
10 processes the request by the mobile station to start an uplink or downlink TBF. When the base station is ready to grant the assignment to the mobile, the zoning logic searches a table or list of existing zones and tries to find one that is appropriate for the mobile station based on the mobile station's carrier-to- interference ratio and reported received power level as sent by  
15 the mobile in the last Signal Quality Report, or in addition or alternatively based on the location of the mobile station. If no such zone exists, then a logical zone is created in which the optimal carrier-to-interference ratio would be achieved using the minimum of power on the downlink signal. The mobile station would then be informed of its channel, and, directly or  
20 indirectly, its zone assignment in the assignment message by way of, for example, communication of a P0 value. The mobile stations are not

required to have any specially designed software or hardware to operate according to various aspects of the invention.

When the base station receives the Channel Quality Report from a mobile station, the logic which is activated to decode such report in turn  
5 activates the zoning logic, which first determines whether the carrier-to-interference ratio is appropriate for the zone in which the mobile station is located or the C/I information of the mobile station downlink signal. The algorithm terminates and no re-assignment of zone or power control range may occur at optimal level at which increasing the downlink power would  
10 not result in better decoder performance. At such an optimal level, 100% of the transmitted signal would be received at this power level.

If the mobile station is assigned to a zone, but its carrier-to-interference ratio is inappropriate for that zone, (i.e., either higher than optimal or too low), then the zoning logic searches a table or list of  
15 existing zones and tries to find one that is appropriate for the mobile based on the mobile station's carrier-to-interference ratio and reported received power level. If no such zone exists, then a logical zone is created in which the optimal carrier-to-interference ratio would be achieved using the minimum of base station power on the downlink signal. Power  
20 control ranges or zones may be dissolved when they are no longer needed. After a TBF ends, the base station removes the mobile station from the

existing zone table or list entry. If the mobile station being removed is the last mobile station in the zone, the zone may be dissolved.

Other communication systems as defined by Enhanced Data for Global Evolution (EDGE) or Enhanced GPRS operate according to similar  
5 standards. The present invention may be used in all or any variations of the mentioned data communication systems.

## Claims

1. In a communication system, a method comprising the steps of:  
  
grouping a plurality of mobile stations into a plurality of groups of mobile stations;  
  
5 assigning a power control range to each group of said plurality of groups of mobile stations, thereby creating a plurality of power control ranges corresponding to said plurality of groups of mobile stations, wherein each power control has a minimum and maximum power level.
2. The method as recited in claim 1 further comprising the step of:  
  
10 controlling at least a downlink signal transmitted from a base station to at least one of said plurality of mobile stations according to one of said plurality of power control ranges corresponding to one of said plurality of groups of mobile stations that includes said least one of said plurality of mobile stations.
- 15 3. The method as recited in claim 2 wherein said downlink signal includes a time slot having at least a first and second data fields, wherein said first data field is intended for a first mobile station and second data field for a second mobile station, wherein said first and second mobile stations included in said one corresponding said plurality of groups of  
  
20 mobile stations.

4. The method as recited in claim 1 wherein said assigning is based on determining location of at least one of said plurality of groups of mobile stations with respect to a base station providing communication services to said plurality of groups of mobile stations.
- 5 5. The method as recited in claim 1 wherein said grouping is based on determining location of at least one of said plurality of mobile stations with respect to a base station providing communication services to said plurality of mobile stations.
6. In a communication system, an apparatus comprising:
- 10 means for grouping a plurality of mobile stations into a plurality of groups of mobile stations;
- means for assigning a power control range to each group of said plurality of groups of mobile stations, thereby creating a plurality of power control ranges corresponding to said plurality of groups of mobile
- 15 stations, wherein each power control has a minimum and maximum power level.
7. The apparatus as recited in claim 14 further comprising:
- means for controlling at least a downlink signal transmitted from a base station to at least one of said plurality of mobile stations according to
- 20 one of said plurality of power control ranges corresponding to one of said

plurality of groups of mobile stations that includes said least one of said plurality of mobile stations.

8. The apparatus as recited in claim 14 further comprising means for determining location, for said means for assigning, of at least one of said  
5 plurality of groups of mobile stations with respect to a base station providing communication services to said plurality of groups of mobile stations.

9. The apparatus as recited in claim 14 further comprising means for determining location, for said means for grouping, of at least one of said  
10 plurality of mobile stations with respect to a base station providing communication services to said plurality of mobile stations.

10. The apparatus as recited in claim 14 further comprising means for assigning a power level reference value to each of said plurality of power control ranges.

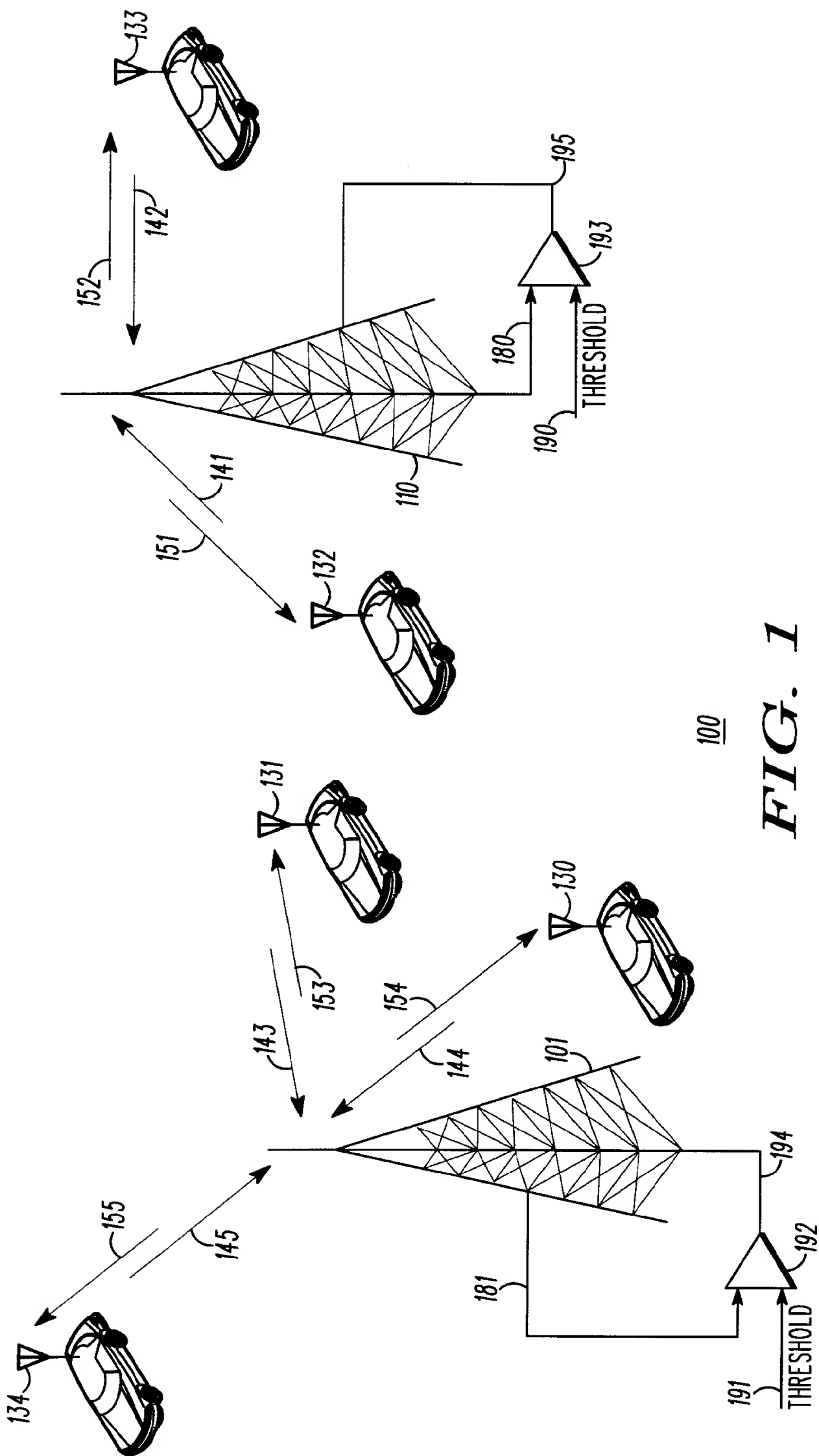


FIG. 1

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/24020

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04B 07/00; H04Q 07/00

US CL : 455/522

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/522, 69, 501

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US 6,101,176 A (HONKASALO, et al) 08 August 2000 (19.08.2000), column 3, line 24 to column 5, line 17.	1-6
Y,E	US 6,137,840 A (TIEDEMANN, et al) 24 October 2000 (24.10.2000), column 3, line 14 to column 4, line 48.	1-6



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

01 November 2000 (01.11.2000)

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# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/24020

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claim Nos.: 7-10  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐  
☐

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.